Fermilab

Particle Physics Division
Mechanical Department Engineering Note

Number: MD-ENG-078 Date: May 10, 2005

Project Internal Reference:

Project:

Title: Mucooler Cryostat Reinforcement Support

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Key Words: Mucooler, cryostat, support, analysis

Abstract Summary:

The existing Mucooler cryostat support design does not consider any external horizontal force acting upon. This force, which can be generated in an accident or during the magnet quenching, can be very high so that a reinforcement of the support system is considered.

Applicable Codes:

Manual of Steel Construction Allowable Design,
Aluminum Design Manual,
Hilti Product Technical Guide

Mucooler Cryostat Support Analysis

PPD/MD Eng Note 078

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(I) Introduction:

The Mucooler cryostat and its support are basically made of stainless steel and aluminum. As shown in Figure 1, the cryostat is supported by two 0.5-inch tie-rods fastened to the 5/8-inch thick aluminum base plate, and 3 simple supports as adjusters via an aluminum triangular frame. A clamping bar with two 3/8" tie-rods is used to press against the triangular frame as well to prevent the cryostat from turning over. The aluminum base plate is then fastened to a E size concrete block which weighs 1,840 lbs. This concrete block is in turn fastened to two 6-inch square aluminum tubes and also to the concrete floor by four 3/8-inch anchor bolts. To support the whole weight of the cryostat and concrete block, an extra 6-inch aluminum square tube is placed under the concrete block as well.

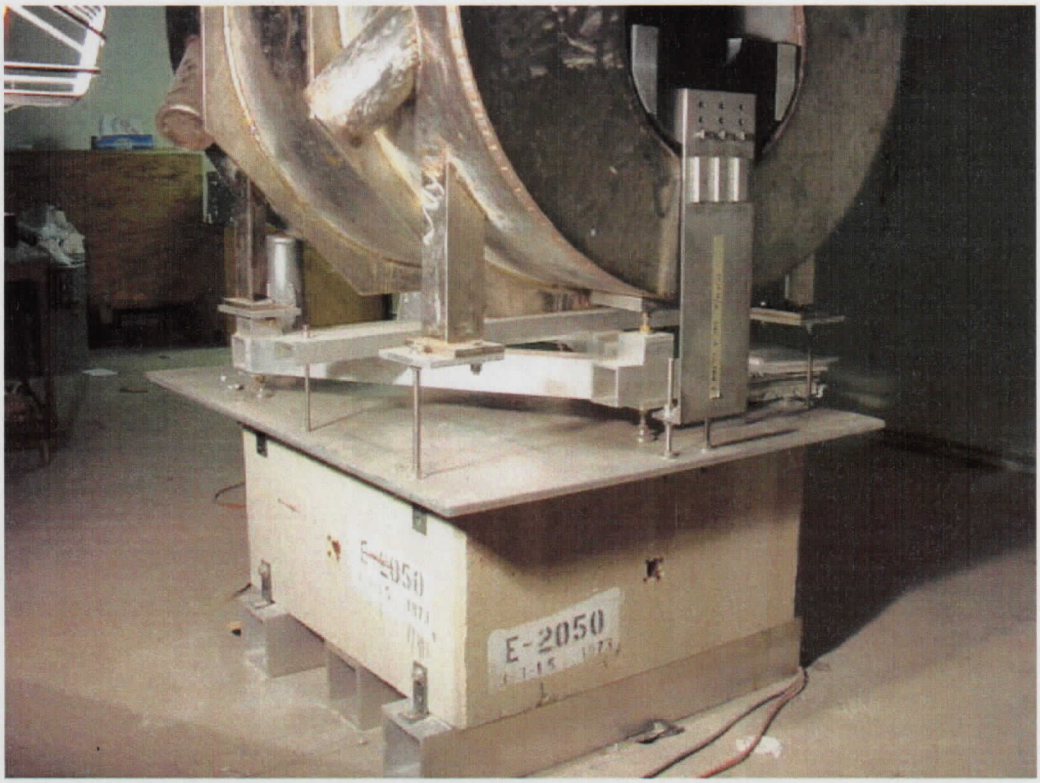


Figure 1. Existing Mucooler Cryostat and its Support

The existing support design does not consider any external horizontal force acting upon. This force, which can be generated in an accident or during the magnet quenching, can be very high so that a reinforcement of the support system should be considered.

Based on the Fringe Field Plot for Muon Magnet – Current Adding (Solenoid Mode), the magnetic field is much stronger in the axial direction than the radial direction. Since there will be another testing cavity (not shown in Figure 1) to be located in front of the cryostat axially as well, so the analysis was concentrated at this axial direction.

By visual inspection, it was estimated the weakest links in this support system are (1) the 3/8-inch Hilti HDI anchor bolts on the concrete floor (2) the tie-rods fastened to the aluminum base plate. For instance, taking the 3/8-inch anchor bolt as an example, preliminary calculations showed that the horizontal loading capacity was under 2,000 lbf as shown below.

Assuming the weight of the cryostat was well supported by the aluminum tubes under the concrete block and an external force P was acting horizontally at the cryostat center along the axis:

As the concrete block structure was very rigid, a lifting reaction force F was created due to the moment equilibrium condition. Referring to the Hilti catalogue on the HDI anchor bolt being used for concrete capacity of 4,000 lbs, the allowable tensile force on the bolts was 1,785 lbf.

The maximum allowable external force P was then equal to

2 bolts*1,785*26.5"/53.16" = 1,780 lbf

Where 26.5" was the distance between the anchor bolts, and
53.16" was the height of the force P from ground level

However, it was a little bit complicated to analyze the tie-rod support system. As the tie-rods were slender, reaction moment and force would both be generated if we assumed the tie-rods were rigidly fastened at ends. Unlike the rigid concrete block which only generated force but no moment, these tie-rods could perform like cantilever rods and generated moment but no force. If we assumed this case as the worst case and let each tie-rod share ¼ of the moment, then we would find the allowable load would be unrealistically small as follows.

The tie-rods were made of stainless steel 304 which had a tensile strength, F_u, 70,000 psi. According to the American Institute of Steel Construction (AISC) manual, the allowable tensile stress (F_t) could be found by:

$$F_t = 0.33 * F_u$$
$$= 0.33 * 70{,}000$$
$$= 23{,}100 \text{ psi}$$

Assuming all rods were of 1/2" diameter with a moment of inertia, I, 0.003067inch^4, the allowable external load was then equal to

$\frac{1}{4} * F_t = (P*d)*R/I$ or

$P = 4* F_t*I /R/d$

Where d = 29.16", the height of the force P from the 5/8-inch thick aluminum base plate
R = 0.25", the radius of the tie-rod

$P = 4 *23,100*0.003068/(0.25"*29.16")$
$= 39$ lbf

Apparently, this allowable force would be even smaller if shear stress was included. This simplified calculation was too conservative and hence Finite Element Analysis (FEA) was needed to figure out how much force and moment were generated. However, to save efforts, the existing support system was skipped and FEA was only done for the reinforced support system.

(II) Magnetic Loading Finite Element Analysis (FEA)

Prior to do the structural analysis for the reinforcement system, additional magnetic loading FEAs were done to see how much external force would be generated in cases of

(1) a steel plate was accidentally left behind in operation
(2) quench occur when a cavity was positioned near by

It was found that 6,310 lbf and 2,190 lbf forces would be generated correspondingly. To cover the worst-worst scenario, it was decided to use 6,000 lbf as the support reinforcement design specification. This force was acting at the center of cryostat horizontally as shown in the red arrow in Figure 2.

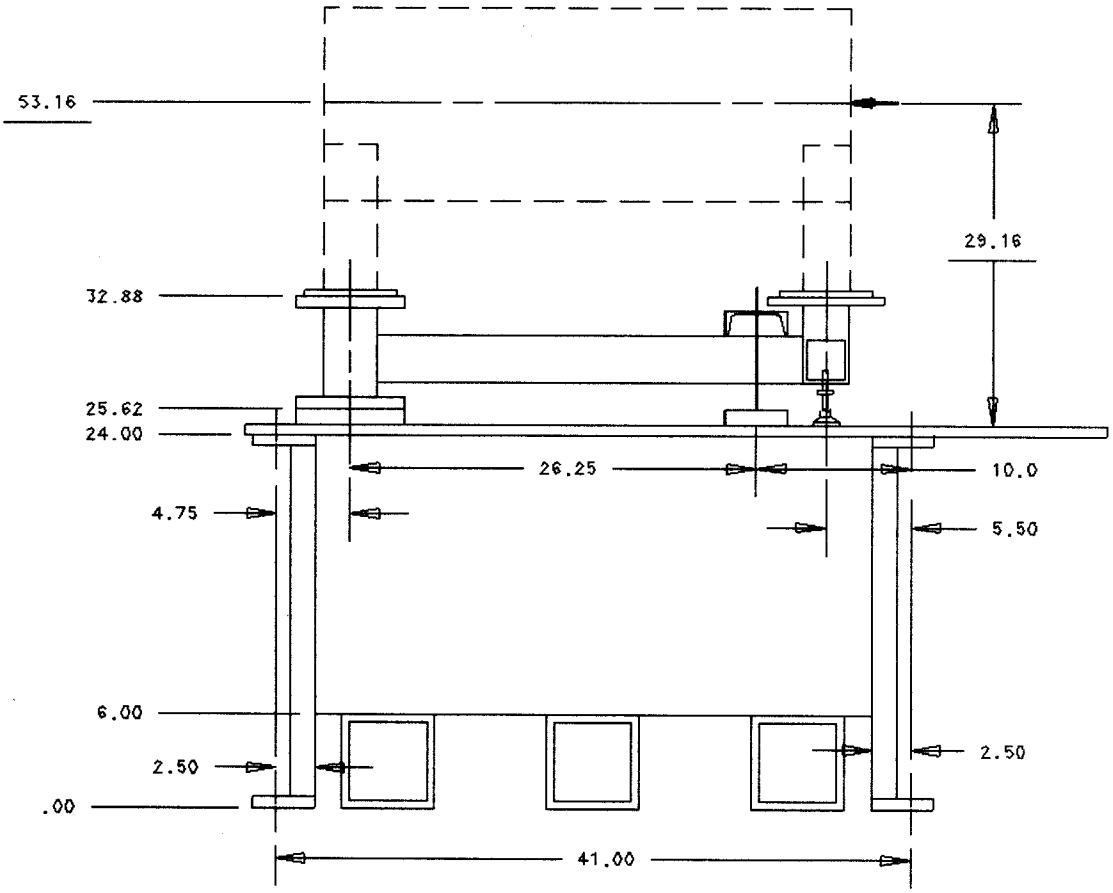


Figure 2. Side View of Reinforced Support for the Mucooler Cryostat

(III) The Conceptual Design for the Reinforcement Support System

The reinforcement support system is shown in Figure 3. Due to the accessibility of the existing set up and the concrete block interference, drilling and tapping holes on the 5/8" aluminum plate would not be easily conducted. The provision of the reinforcement rigid support is thus made by welding one-inch thick aluminum plates with threaded holes on the existing 5/8-inch aluminum plate. Stainless steel parts will then be fastened to these plates for reinforcing the support accordingly. To best use the stability feature provided by the concrete block, additional support provided by aluminum channel C4 fastened to concrete block, floor and plate altogether is planned.

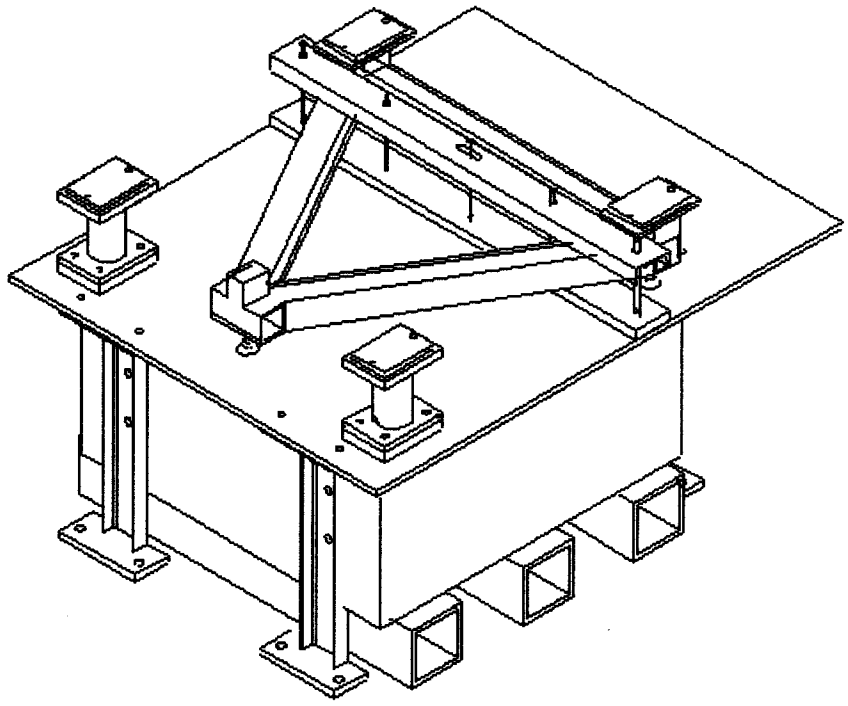


Figure 3. The Reinforcement Support System for Mucooler Cryostat

The reinforcement is basically to address the following areas:

Anchor:

- Keep the existing anchors on the 6-inch aluminum square tube.
- Attach aluminum channels C4 welded with end plates to the concrete block using Hilti 3/4-inch stud type
- Fasten the channel to the concrete floor using Hilti 3/4-inch stud type anchors
- Fasten the channel to the 5/8" aluminum base plate with regular ½" stainless steel bolts

Cryostat support:

- Replace the existing ½" tie-rods with 3-inch pipe assembly
- Weld aluminum plate 1-inch thick with threaded holes to the existing 5/8-inch aluminum base plate
- Fasten the existing cryostat supports with high strength bolts

Clamping:

- Relocate the clamping position on the triangular frame to the rear instead of middle
- Weld 1-inch thick aluminum bar to the existing aluminum base plate to provide threaded holes for tie-rods

- Use five ½" stainless steel tie-rods to press aluminum C4 channel against the triangular frame

(IV) Structural Loading Finite Element Analysis (FEA)

After the conceptual design was made, FEA was used to find out the generated loadings on the supports. To simplify the analysis, half of the support system with parts above the 5/8-inch aluminum base plate was modeled in FEA. The points of interest were labeled as A, B, and E in Figure 4 in which A and B were the connection points between the existing support of the Mucooler cryostat to the additional support system while E was the connection point between the extended rigid support to the 5/8-inch aluminum plate.

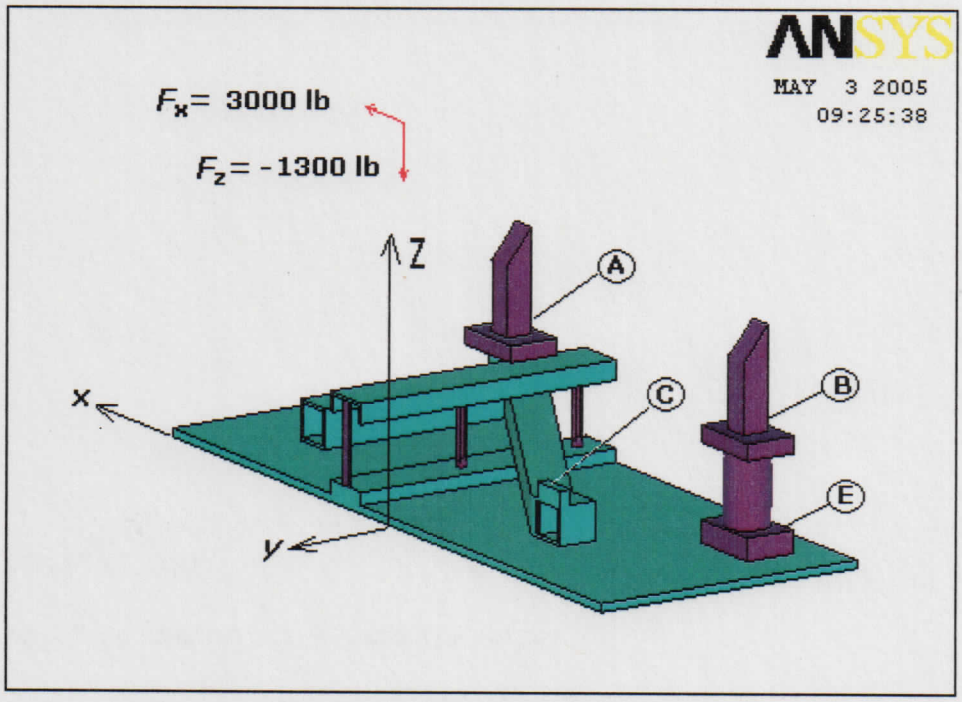


Figure 4. FEA Half Model for Cryostat Support

Two cases were analyzed. The external applied 6,000 lbf force could be acted axially at the center of Mucooler vessel from either end. Dead weight of the cryostat including 150 liters of liquid helium totaling 2,600 lbf was also added in this FEA. Since half model was analyzed, half amount of these input forces would be used. The generated loads computed by the FEA were then shown in Table 1 with X, Y, Z notations referred to Figure 4.

Load Case 1. Applied force Fx in positive X direction				
	A	B	C	E
FX	139	2,167	695	2,167
FZ	(2,254)	962	(23)	938
MY	790	12,937	(63)	31,898
Load Case 2. Applied force Fx in negative X direction				
	A	B	C	E
FX	(203)	(2,159)	(638)	(2,159)
FZ	915	(1,929)	(301)	(1,953)
MY	(1,253)	(12,850)	(66)	(31,752)

Table 1. FEA Results at Points of Interest

Results were about the same. The results of Load Case 2 were used as it was slightly larger generally. Also, as loadings at point B were higher than point A for the similar connection, results at point B were used for further analysis. Loading at connection point C was too low to be skipped.

(V) Allowable Stress Calculations

Unless stated otherwise, the allowable strengths of the stainless steel parts used in this calculation are referred to Table 2. The American Institute of Steel Construction (AISC) manual was referred. The allowable tensile stress (F_t), allowable bending stress (F_b) and the allowable shear stress (F_v) were obtained by multiplying a safety either to the tensile strength, (F_u) or to the yield strength (F_y) as following. Allowable tensile and shear stresses are listed in the last two columns in this table.

Stainless steel plate, compact section: $F_b = 0.75 * F_y$; $F_v = 0.40 * F_u$
Stainless steel pipe, non- compact section: $F_b = 0.60 * F_y$; $F_v = 0.40 * F_u$
Stainless steel fastener, threads in shear plane: $F_t = 0.33 * F_u$; $F_v = 0.17 * F_u$

All strengths in ksi items	Minimum tensile F_u	Minimum Yield F_y	Safety tensile	Safety shear	Allowable tensile F_t or F_b	Allowable shear F_v
SS 304 plate	85.00	35	0.75	0.40	26.25	14.00
SS 304 pipe	85.00	35	0.60	0.40	21.00	14.00
SS 304 bolt	95.00	60	0.33	0.17	31.35	16.15
SS 304 tie-rod	70.00	30	0.33	0.17	23.10	11.90
SS 316 (Bumax) bolt	116.00	30.00	0.33	0.17	38.28	19.72
SS 308 fillet weld	88.50			0.30	-	26.55

Table 2. Allowable Strengths in ksi for Stainless Steel Parts

Similarly, the allowable strengths of the aluminum parts used in this calculation are referred to Table 3. The Aluminum Design Manual was referred. The allowable tensile and shear stresses are listed in the last two columns in this table.

All strengths in ksi	Yield tensile	Yield shear	SF	Allowable Tensile & compression	Allowable shear
items	F_y	S_y		F_t	F_y
Al T6 plate & Channel	35.00	20.00	0.6	28.00	12.00
Al T6 plate, welded	15.00	9.00	0.6	11.82	7.09
Al 5356 weld					7.00

Table 3. Allowable Strengths in ksi for Aluminum Parts

Stress analyses based on allowable stress design are as shown in the following item by item.

1. Two ½"diameter stainless steel bolts at B

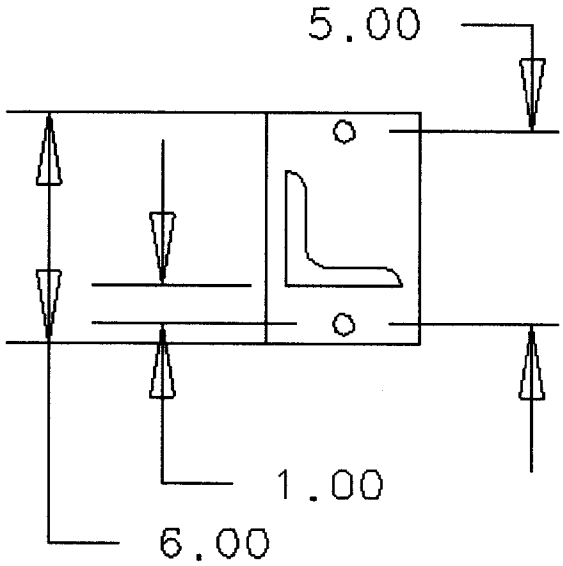


Figure 5. Existing Cryostat Support

Cross sectional area of bolt, A_x = 0.1963 inches^2
Stress area of bolt, A_s = 0.1419 inches^2

Shear stress, Ss = (FX at B)/2 bolts/A_x
= 2,159/2/0.1963
= 5,499 psi

Normal stress, S_n = (FZ at B)/2 bolts/ A_s
= 1,929/2/0.1419
= 6,797 psi

Bending stress, S_b = (MY at B)/(bolts span)/A_s where span = 5"
= 12,850/5/0.1419
= 18,111 psi

Total normal stress, S_{n_total} = $S_n + S_b$
= 24,908 psi

Check if (Ss)/(Ss _allowable) + (S_n _total)/(S_n _allowable) < 1.0

(6,797/16,150) + (24,908/31,350) = 1.22 > 1.0.....Not OK

Regular stainless steel 304 bolt did not pass, select high strength stainless steel 316-L bolt with F_u = 116,000 psi

(6,797/19,720) + (24,908/38,280) = 0.99 < 1.0.....OK

2. 0.5"X6"X4" stainless steel plate at B

Referring to Figure 5, an existing 3X0.375 angle had been welded on this stainless steel plate. A lifting force, F_b, will be generated at the outer edge of the angle beam due to the moment. Consequently, another moment will be generated with reference to the bolt centers support. The lever arm distance, L, between the outer edge of the angle beam and the bolt center is 1".

Force on beam edge, F_b = (MY at B)/(angle length)
= (12,850/3)
= 4,283 lbf

Plate moment, M_p = F_b *L
= 4,283*1
= 4,283 in-lbf

Bending stress, S_b = 6* M_p /(b*t^2) where b = 4" and t = 0.5"
= 6*4,283/(4*0.5^2)
= 25,700 psi < Allowable stress of 26,250.....OK

3. ¼" weld around 3" stainless steel pipe at E (loading at E is > at B)

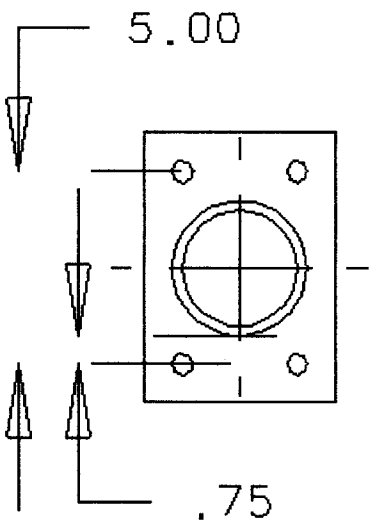


Figure 6. Top view of 3-inch pipe support with end plate

Pipe OD, sch 40 = 3.5"

Total weld area, A_w = π*3.5*.25*.707
= 1.94 inch^2

Moment of Inertia of weld, I_w = π*R^3*t
= 3.14159*1.75^3*.25*.707
= 2.976 inches^4

Shear stress, Ss = (FX at E)/ A_w
= 2,159/1.94
= 1,113 psi

Normal stress, S_n = (FZ at E)/ A_w
= 1,953/1.94
= 1,007 psi

Bending stress, S_b = (MY at E)*R/ I_w
= 31,752*1.75/2.976
= 18,671 psi

Total normal stress, S_{n_total} = S_n + S_b
= 19,678psi

Total resultant stress, S_R = SQRT(1,113^2 + 19,678^2)
= 19,709 psi

This stress is needed to be smaller than the lower allowable stress of base material and filler material. As filler material strength was lower than that of the base material, allowable shear stress of filler material governs.

i.e. 19,709 < 26,550 .....OK

4. 3" stainless steel pipe at E

   Wall thickness of 3" pipe is ¼", the same as the weld size but with cross-sectional area actually larger. In addition, the allowable stress of stainless steel is higher than that of the filler material, the stresses on this pipe can thus be reasonably concluded within the allowable stress limit.

5. Four ½"diameter stainless steel bolts at E

   Referring to Figure 6,

   Shear stress, Ss = (FX at E)/4 bolts/ A_x
   = 2,159/4/0.1963
   = 2,750 psi

   Normal stress, S_n = (FZ at E)/4 bolts/ A_s
   = 1,953/4/0.1419
   = 3,441 psi

   Bending stress, S_b = (MY at E)/2 bolts/(bolts span)/A_s where span = 5"
   = 31,752/2/5/0.1419
   = 22,376 psi

   Total normal stress, S_n _total = $S_n + S_b$
   = 25,817 psi

   Check if (Ss)/(Ss _allowable) + (S_n _total)/(S_n _allowable) < 1.0

   Stainless steel bolt s304 ASTM F593 C are used

   (2,750/16,150) + (25,817/31,350) = 0.99 < 1.0.....OK

6. 0.75"x5"x7" stainless steel end plate at E

   Referring to Figure 6, a 3-inch pipe is welded on this stainless steel plate. A lifting force, F_b, will be generated at the outer edge of the pipe due to the moment. Consequently, another moment will be generated with reference to the bolt center support. The lever arm distance, L, between the outer edge of the pipe and the bolt center is 0.75" as shown.

Force on pipe edge, F_b = (MY at E)/(pipe OD)
= (31,752/3.5)
= 9,072 lbf

Plate moment, M_p = F_b *L
= 9,072*0.75
= 6,804 in-lbf

Bending stress, S_b = 6* M_p /(b*t^2) where b = 5" and t = 0.75"
= 6*6,804/(5*0.75^2)
= 14,515 psi < Allowable stress of 26,250.....OK

7. 1"x5"x7" aluminum boss plate at E

A lifting force, F_b, will be generated at the threaded holes of the plate due to the moment. Consequently, another moment will be generated with reference to the welded edge support. The lever arm distance, L, between the threaded hole center to the welded edge is 1".

Force on threaded hole, F_b = (FZ at E)/2 bolts + (MY at E)/bolt span/2 bolts
= (1,953/2) + (31,752/5/2)
= 4,152 lbf

Plate moment, M_p = F_b *L
= 4,152*1
= 4,152 in-lbf

Bending stress, S_b = 6* M_p /(b*t^2) where b = 5" and t = 1"
= 6*4,152/(5*1^2)
= 4,982 psi < Allowable stress of 28,000.....OK

With reference to the Aluminum Design Manual, the allowable pull out force on the threads based on the engagement depth, P_{not}, can be calculated from:

Pull out force, P_{not} = 0.85*t_c*D*F_{tu2}
where t_c is the depth of screw threads penetration in the aluminum plate
D is the nominal screw diameter
F_{tu2} is the tensile ultimate strength of aluminum

= 0.85*.75*.5*42,000
= 13,388 lbf > 3,663 lbf.....OK

8. 5/16" weld around aluminum 1"x5"x7" boss plate for pipe support at E

Throat dimension, t_w = .3125*.707

= .221"

Total weld length, L_w = 2*(5+7)
= 24

Total weld area, A_w = 24*.221
= 5.30 inch^2

Moment of Inertia of weld, I_w = summation of ($b*d^3/12 + A*z2$)
= ($2*.221*7^3/12$) + ($2*.221*5*3.5^2$)
= 39.71 inches^4

Shear stress, S_s = (FX at E)/A_w
= 2,159/5.30
= 407 psi

Normal stress, S_n = (FZ at E)/A_w
= 1,953/5.30
= 368 psi

Bending stress, S_b = (MY at E)*c/I_w
= 31,752*3.5/39.71
= 2,799

Total normal stress, $S_{n, total}$ = $S_n + S_b$
= 3,167 psi

Total resultant stress, S_R = SQRT($407^2 + 3,167^2$)
= 3,193 psi

This stress is needed to be smaller than the lower allowable stress of base material and filler material. However, the allowable strength of the base material will be lower if welding on this part is too much. According to the Aluminum Design Manual, the effect of welding cannot be neglected if A_w is equal to or greater than 15% of A, and the allowable stresses should be adjusted as follows.

$F_{pw} = F_n - (A_{w/} A)*(F_n-F_w)$

Where

F_{pw} = allowable stress on cross section, part of whose area lies within 1" of weld

F_n = allowable stress for cross section 1" or more from weld

F_n = $1.3* S_y / n_y$ where n_y is the factor of safety
= 1.3*20/1.65
= 5,760 psi for shear;

F_n = $1.3* F_y / n_y$

$= 1.3*35/1.65$
$= 27{,}580$ psi for tension

F_w = allowable stress on cross section if entire area were to lie within 1" of weld

$F_w = 1.3* S_y / n_y$
$= 1.3*9/1.65$
$= 7{,}090$ psi for shear;

$F_w = 1.3* F_y / n_y$
$= 1.3*15/1.65$
$= 11{,}820$ psi for tension

A_w = the portion of area of cross section A lying within 1" of a weld

A = net area of cross section of a member

Hence, (A_w / A) $= 2/5$
$= 0.4 > 15\%$

F_{pw} for shear $= 15{,}760 - (0.4)*(15{,}760-7{,}090)$
$= 12{,}290$ psi

F_{pw} for tension $= 27{,}580 - (0.4)*(27{,}580-11{,}820)$
$= 21{,}270$ psi

Aluminum alloy 5356 is used for the fillet weld, the allowable shear stress is equal to 7,000. As this have lower strength than that of the parent part, the fillet weld strength governs the design.

i.e. $3{,}193 < 7{,}000$ .....OK

9. 0.625"x44"x55" aluminum T6 base plate

A lifting force, F_p, at the clamping support would be generated by the applied horizontal force. Referring to Figure 2, this loading can be computed directly by the moment equilibrium.

$F_p = 6{,}000*29.16/26.25$
$= 6{,}665$ lbf

Where 26.25" is the distance between the fastened support and clamping support.

As the supports to the concrete block is much farther, a moment will be generated between this lifting force, F_p, and the end support to concrete. This longer lever arm distance, L = 10", is used as the worst case analysis.

Plate moment, $M_p = F_p * L$
$= 6{,}665*10$
$= 66{,}650$ in-lbf

Bending stress, S_b = $6* M_p /(b*t^2)$ where b = 44" and t = 0.625"
= $6*66,650/(44*0.625^2)$
= 23,266 psi < Allowable stress of 28,000.....OK

10. 5/16" weld around aluminum 1"x4"x44"" boss plate for clamping support

Intermittent fillet weld 2" long with 2" space on the long side only

Total weld length, L_w = 2*(22)
= 44"

Total weld area, A_w = 44*.221
= 9.72 $inch^2$

Same amount of reaction force FZ, 6,665 lbf, will act upon this part.

Normal stress, S_n = $(FZ)/A_w$
= 6,665/9.72
= 686 psi < Allowable stress of 7,000.....OK

11. Five ½" stainless steel tie-rods for clamping support

Stress area of tie-rod, A_s = 0.1419 $inch^2$

Normal stress, S_n = (FZ at clamping)/5 tie-rods/A_s
= 6,665/5/.1419
= 9,394 psi < Allowable stress of 23,100.....OK

12. Five ½" threaded holes on aluminum clamping support

Normal force, F_n = (FZ at clamping)/5 tie-rods
= 6,665/5
= 1,333 lbf

Which is < allowable pull out force 13,388 lbf as determined previously.....OK

13. Eight ½" stainless steel bolts for Channel C-4 end-plates attached to 5/8" aluminum plate

Cross sectional area of bolt, A_x= 0.1963 $inches^2$
Stress area of bolt, A_s = 0.1419 $inches^2$

Shear force, FX = 6,000/8 bolts
= 750 lbf

Normal force, FZ = 6,000*29.16/41/4 bolts
= 1,067 lbf

Where 41" is the distance between the channel supports as referring to Figure 2.

Shear stress, S_s = (FX)/A_x
= 750/.1963
= 3,820 psi

Normal stress, S_n = (FZ)/A_s
= 1,067/.1419
= 7,518 psi

(3,820/16,150) + (7,803/31,650) = 0.67 < 1.0.....OK

14. 5/16" weld around aluminum Channel C4x2.50 with end-plate on floor

Total weld length, L_w = 2*(4+1.72+1.4)
= 14.24"

Total weld area, A_w = 14.24*.221
= 3.147 inch^2

Shear force, FX = 6,000/4 supports
= 1,500 lbf

Normal force, FZ = 6,000*53.16/41/2 supports
= 3,890 lbf

Shear stress, S_s = (FX at floor support)/A_w
= 1,500/3.147
= 477 psi

Normal stress, S_n = (FZ at floor support)/A_s
= 3,890/3.147
= 1,236 psi

Due to the possible interference of the drilling machine with the concrete block when drilling holes on floor, the hole centers have an offset and it will create a bending stress on the weld. To simplify the calculation, the weld is assumed to have a weld path as shown in Figure 7.

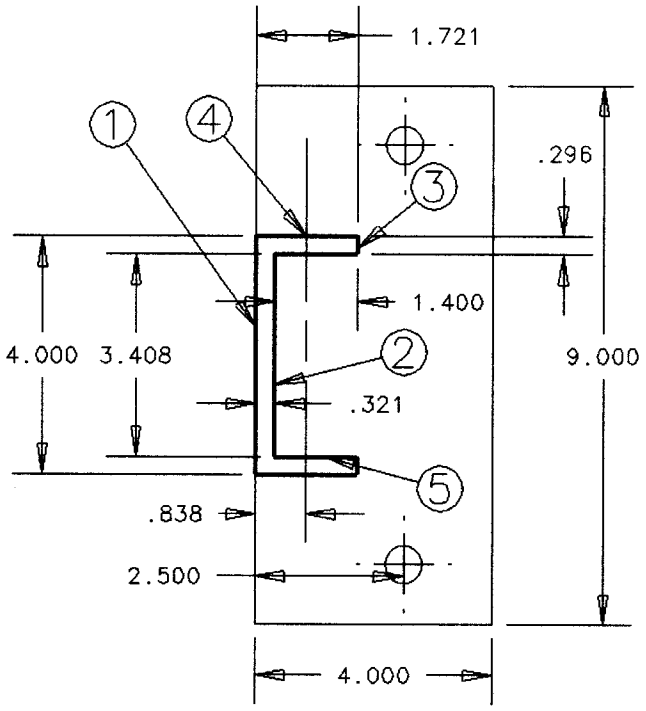


Figure 7. End Plate Design for Channel C4

It is needed to calculate the center of gravity (CG) of the weld and its corresponding moment of inertia about the bending axis. This CG distance is found to be 0.838" from channel base as shown in Figure 7. Further calculations are done for the 5 line segments of weld, and the results are shown in Table 4.

Line sectment	1	2	3	4	5
d to CG	0.838	0.517	0.883	0.023	0.183
I_{yy}	0.004	0.003	0.001	0.188	0.101
$A*x^2$	0.621	0.201	0.102	0.000	0.021
I_{cg}	0.624	0.204	0.103	0.188	0.122

Table 4. Results of individual weldment properties

The total I_{cg} is then equal to1.241 inch4, and the farthest fiber distance, c, is:

c = 1.721 – 0.838"
= .883"

Moment, M_w = FZ*d
= 3,890*(2.5-.838)
= 6,465 in-lbf

Bending stress, S_b = $(M_w)*c/I_{cg}$

$= 6{,}465*.883/1.241$
$= 4{,}601$ psi

Total normal stress, $S_{n,\,total}$ $= S_n + S_b$
$= 5{,}837$ psi

Total resultant stress, S_R $= SQRT(477^2 + 5{,}837^2)$
$= 5{,}856$ psi

To check the welding influence on the allowable stresses of base material:

A_w = the portion of area of cross section A lying within 1" of a weld
A = net area of cross section of a member

Hence, (A_w/A) $= 2.72/4$
$= 0.68 > 15\%$

F_{pw} for shear $= 15{,}760 - (0.68)*(15{,}760-7{,}090)$
$= 9{,}680$ psi

F_{pw} for tension $= 27{,}580 - (0.68)*(27{,}580-11{,}820)$
$= 16{,}860$ psi

Aluminum alloy 5356 is used for the fillet weld, the allowable shear stress is equal to 7,000. As this have lower strength than that of the parent part, the fillet weld strength governs the design.

i.e. 5,856 < 7,000 .....OK

15. Aluminum end plate .75"x9"x4" for Channels C-4x7.25

Referring to Figure 7, a moment, M_p, will be generated due to the lifting force, F_p, and the offset, L, of the channel and the bolt center support. The lever arm distance, L, can be calculated as:

L $= (2.5-.838)$
$= 1.662$"

Plate moment, M_p $= F_p * L$
$= 3{,}890*1.662$
$= 6{,}465$ in-lbf

Bending stress, S_b $= 6* M_p /(b*t^2)$ where b = 9" and t = 0.75"
$= 6*6{,}465/(9*0.75^2)$
$= 7{,}662$ psi < Allowable stress of 28,000.....OK

16. Four aluminum Channels C4x2.50

The web thickness of this channel is 0.32"

Two through holes of diameter 0.6875" are drilled on this channel.

Bearing area, A_b = 0.32*0.6875
= 0.22

Shear force, FX = 6,000*53.16/41/4 holes
= 1,945 lbf

Shear stress, S_n = (FX at holes of channel)/A_b
= 1,945/0.22
= 8,841 psi < allowable shear 12,000.....OK

17. Eight 3/4" carbon steel Hilti stud anchors for concrete block

As a conservative but simplified analysis, the contribution of the existing 3/8" anchor bolt is ignored.

Shear force, FZ = 6,000*53.16/41/4 bolts
= 1,945 lbf

Normal force, FX = 6,000/8 bolts
= 750 lbf

TABLE 3—CARBON STEEL KWIK BOLT 3 ALLOWABLE TENSION AND SHEAR VALUES IN NORMAL-WEIGHT CONCRETE (in pounds)[1,2,4]

Anchor diameter (inch)	Anchor depth (inches)	f'c = 2,000 psi Tension		f'c = 3,000 psi Tension		f'c = 4,000 psi Tension		f'c = 6,000 psi Tension		Shear[4]
		With Sp. Insp.[3]	Without Sp. Insp.	With Sp. Insp.[3]	Without Sp. Insp.	With Sp. Insp.[3]	Without Sp. Insp.	With Sp. Insp.[3]	Without Sp. Insp.	
1/4	1 1/8	276	138	338	169	399	200	510	255	449
	2	594	297	669	335	745	372	766	383	449
	3	661	331	714	357	766	383	766	383	449
3/8	1 5/8	678	339	846	423	1,013	506	1,013	506	1,062
	2 1/2	1,179	590	1,424	712	1,669	835	1,846	923	1,255
	3 1/2	1,450	725	1,560	780	1,669	835	1,846	923	1,255
1/2	2 1/4	1,049	524	1,284	642	1,519	759	1,853	927	1,745
	3 1/2	1,810	905	2,048	1,024	2,286	1,143	3,035	1,518	1,867
	4 3/4	2,000	1,000	2,207	1,103	2,414	1,207	3,083	1,541	1,832
5/8	2 3/4	1,766	883	1,898	949	2,029	1,015	2,601	1,300	2,578
	4	2,469	1,235	2,805	1,402	3,141	1,570	3,825	1,912	3,324
	5 1/2	3,079	1,539	3,462	1,731	3,846	1,923	4,992	2,496	3,324
3/4	3 1/4	1,949	974	2,230	1,115	2,510	1,255	3,475	1,738	3,834
	4 3/4	3,007	1,503	3,956	1,978	4,905	2,452	5,714	2,857	4,701
	6 1/2	4,173	2,087	5,369	2,685	6,565	3,283	6,565	3,283	4,701

18. Eight 3/4" carbon steel Hilti stud anchors on concrete floor

As a conservative but simplified analysis, the contribution of the existing 3/8" anchor bolt is ignored.

The distance between the anchor bolts within each support is set at 9". No adjustment is needed for edge, but for spacing, the adjustment factors are 0.97 for shear and 0.88 for tension. So the allowable loads are:

Shear : 4,701*.97 = 4,560 lbf
Tension: 2,452*.88 = 2,158 lbf

Shear force, FZ = 6,000/8 bolts
= 750lbf

Normal force, FX = 6,000*53.16/40/4 bolts
= 1,994 lbf

Check if $(S_s)/(S_{s,allowable})^{(5/3)} + (S_{n,total})/(S_{n,allowable})^{(5/3)} < 1.0$

$(750/4,560)^{(5/3)} + (1,994/2,158)^{(5/3)} = 0.93 < 1.0$.....OK

19. Three existing 6"x6"x0.5" aluminum tubes on concrete floor

It is estimated that these tubes support all the dead weight including the 1,840-lb-concrete block

Total support area, A_x = .5*36*6 walls
= 108 inch^2

Normal force, FX = 2,600 + 1,840
= 4,440 lbf

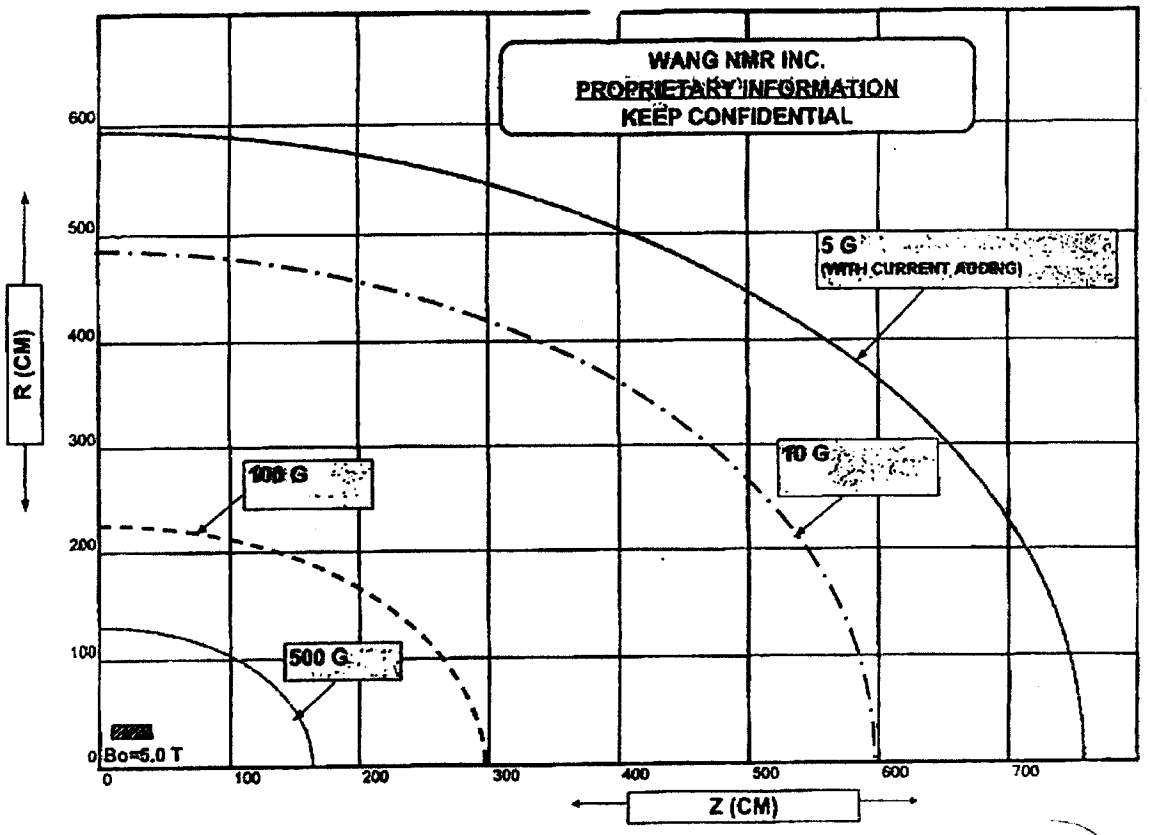
Normal stress, S_n = (FX at tubes)/A_x
= 4,440/108
= 41psi .....OK

(VI) Conclusion

This reinforcement support system is OK to resist a horizontal force 6,000 lbf acting on cryostat center axially.

(VII) Appendix

Fringe Field Plot for Muon Magnet – Current Adding (Solenoid Mode)
Stainless Steel 304 Bolt Properties
Stainless Steel 316L Bolt Properties
Stainless Steel 304 Tie-Rod Properties
Stainless Steel Welding Material 308 Properties
Recommended Aluminum alloy Filler Metals
Allowable Shear Stresses in Fillet Welds
Shielding Blocks and Beams Information
FEA Report – Magnetic Force on a Steel Plate near Solenoid (hard copy only)
FEA Report – Magnetic Force on a Cavity near Solenoid (hard copy only)
Drawing 9209.050-ME-435253 (hard copy only)
Drawing 9209.050-MD-435256 (hard copy only)
Drawing 9209.050-MB-435258 (hard copy only)
Drawing 9209.050-MD-435259 (hard copy only)
Drawing 9209.050-MD-435260 (hard copy only)
Drawing 9209.050-MC-435261 (hard copy only)
Drawing 9209.050-MC-435278 (hard copy only)



FRINGE FIELD PLOT FOR MOUN MAGNET- CURRENT ADDING (SOLENOID MODE)

F593, F594 - ASTM F593 is a specification for stainless hex head cap screws: ASTM F594 is for stainless nuts. Compared to regular (18-8) stainless fasteners, F593 and F594 call for: (a) tensile requirements about 20% higher than that of commercial 18-8 or stainless hex caps and nuts to MS Specifications (MS35307-8, MS34649-50); (b) both a minimum and a maximum tensile and hardness requirements while commercial and MS fasteners do not have a maximum; (c) chemical requirements that (eliminate) many commonly used mixtures of 300 or 18-8 stainless while allowing others. (courtesy Star Stainless Screw)

				Full Size Tests			Machined Specimen Tests		
Stainless Alloy Group	Condition	Alloy Mechanical Property Marking	Nominal Diameter	Tensile Strength ksi c	Yield Strength ksi c/d	Rockwell Hardness	Tensile Strength ksi d	Yield Strength ksi c/d	Elon-gation in 4D %
303, 304, 305, 384, XM1, XM7,302Se	CW1	F593 C	1/4 to 5/8	100 to 150	65	B95 to C32	95	60	20
	CW2	F593 D	3/4 to1-1/2	85 to 140	45	B80 to C32	80	40	25
316	CW1	F593 G	1/4 to 5/8	100 to 150	65	B95 to C32	95	60	20
	CW2	F593 H	3/4 to 1-1/2	85 to 140	45	B80 to C32	80	40	25

Condition - CW - Hardened and rolled from annealed stock, thus acquiring a degree of cold work, sizes .75 in and larger may be hot worked
<c> Yield Strength is the stress at which an offset of .2% gage length occurs
<d> Machined from strain hardened stock
Extra Note - The industry standard of thread length of twice the diameter + 1/4 or 1/2 (depending on the length) does not necessarily apply on the F593 spec. If thread length is important, be sure to cover this with your supplier)

Stainless Steel 304 Bolt Properties

High-Strength Corrosion-Resistant—Hex Socket

Screws have Class 3A thread fit and meet ANSI/ASME B18.3. Length is measured from under head. **A286 super alloy**— 26% nickel and 15% chrome with corrosion resistance similar to 18-8 stainless steel and strength properties comparable to alloy steel. A286 is considered an iron-based super alloy. Conforms to AMS (Aerospace Material Specification) 5737. Passivated (a nitric acid treatment that creates a passive film to protect against oxidation and corrosion) to QQ-P-35. Rockwell hardness: C38-C43. Tensile strength: 160,000-180,000 psi. **Bumax 88 stainless steel**— Type 316L stainless steel with a high molybdenum content offers corrosion resistance similar to Type 316 stainless steel. May be mildly magnetic. Rockwell hardness: not rated. Minimum tensile strength: 116,000 psi.

A286 Super Alloy

Lg.	Each	Lg.	Each
2-56		**8-32 (Cont.)**	
3/16"	92423A411 † $1.19	3/4"	92423A489 † $1.58
1/4"	92423A413 † 1.19	1"	92423A491 † 1.69
5/16"	92423A416 † 1.27	**10-32**	
3/8"	92423A419 † 1.34	3/8"	92423A502 † 1.58

Bumax 88 Stainless Steel

Lg.	Each	Lg.	Each
1/4"-20		**1/2"-13**	
1/2"	92488A216 † $0.83	1"	92488A321 † $3.35
5/8"	92488A219 † .84	1 1/4"	92488A324 † 3.60
3/4"	92488A222 † .89	1 1/2"	92488A328 † 4.42
1"	92488A225 † .93	2"	92488A331 † 4.17

Stainless Steel 304 Bolt Properties

flat washers **lockwashers**		Magnetic permeability - 2.0 max.
	Medium lock - dimensions to ANSI B18.21.1	Lock - Hardness - 35 Rockwell C min. Magnetic permeability - 2.0 max. Washer should have capacity to compress flat and show definable rebound upon release
	Light lock - see chart in catalog	
18-8, 316 **carriage bolts** **hex lag bolts**	Carriage - head and body dimensions to ANSI B18.5 Thread dimensions to class 2A fit, ANSI B1.1 Thread length: see chart in catalog	Cold formed - tensile, yield and hardness increase sharply during cold-formed manufacturing of stainless. Figures below are approximate and are often much higher than shown. Tensile - 100,000-125,000 psi Yield - 55,000-75,000 psi Hardness - 100 Rockwell B Elongation - 30% Reduction in area - 40% Magnetic permeability - 2.0 max.
	Lag - head, body and thread dimensions to ANSI B18.2.1 Thread length: see chart in catalog	
18-8 **shoulder bolts**	Head, body and socket dimensions to ANSI B18.3 Thread dimensions to class 3A fit, ANSI B1.1	Tensile - 70,000 psi min. Yield - 30,000 psi min. Hardness - 55 Rockwell B min.
18-8, 304, 316 **threaded rod**	Thread dimensions to class 1A or class 2A, ANSI B1.1 Pressure applied in rol threading stainless rod causes the rod to elongate or stretch. As the rod stretches, the pitch diameter is reduced which may, in turn, reduce the thread class.	Tensile - 70,000 psi min. Yield - 30,000 psi min. Hardness - 70 Rockwell B min. Elongation - 30% min. Reduction in area - 40% min. Magnetic permeability - 2.0 max.
410 hardened with bright finish **self-drilling screws**	Body, thread, and point dimensions to ANSI B18.6.4 Tensile - 180,000 psi heat-treated	Yield - 150,000 psi heat-treated Hardness - 40 Rockwell C min.
18-8, 304, 316 **MS-AN-NAS-ASTM** **Fasteners**	To government or consensus specification as required	To government or consensus specification as required
18-8, 316 (A2 & A4) **metric fasteners**	To DIN standard as required	To DIN standard as required
Aluminum **Hex Head Cap Screws** **Finished Nuts** **Machine Screws Nuts** **Flat Washers** **Lockwashers** **Threaded Rod**	Hex caps - head and body dimensions to ANSI B18.2.1 Thread dimensions to class 2A fit, ANSI B1.1 Thread length - see chart in catalog	Tensile, yield, and hardness vary sharply depending on the alloying metal mixed with aluminum and the type of heat treatment. Lowest tensile strength is 6061, with 2024 in the middle, and 7075 at the highest strength. Hardness is not considered an important specification in aluminum. Tensile - 37,000-75,000 psi Yield - 30,000-50,000 psi Hardness - B40-B90 Elongation - 10%
	Finished nuts - thickness and width across flats to ANSI B18.2.2 Thread dimensions to class 2B, ANSI B1.1	
	Machine screw nuts - thickness and width across flats to ANSI B18.6.3 Thread dimensions to class 2B, ANSI B1.1	
	Flat washers - see chart in catalog	
	Lockwashers - dimensions to ANSI B18.21.1	

Stainless Steel 304 Tie-Rod Properties

TECHALLOY 308

I. **DESCRIPTION**: Techalloy 308 is used for TIG, MIG, and submerged arc welding of unstabilized stainless steels such as Types 301, 302, 304, 305, 308. This filler metal is the most popular grade among stainless steels, used for general purpose applications where corrosion conditions are moderate. Can also be certified as ER308H.

II. **APPROVALS**: Manufactured under Quality System approved by ASME, ISO9001. Meets AWS 5.9 Class ER308. Approved by Canadian Welding Bureau.

III. **CHEMICAL COMPOSITION**

Carbon	.05
Manganese	1.65
Silicon	.46
Chromium	20.45
Nickel	9.85
Molybdenum	.1
Sulfur	.005
Phosphorus	.016
Nitrogen	.04

MECHANICAL PROPERTIES

Tensile Strength	
88,500 PSI	610 MPA
Yield Strength	
59,500 PSI	410 MPA
Elongation	39%

Stainless Steel Welding Material 308 Properties

March 1995

Table 7.2-1
Recommended Aluminum Alloy Filler Metals for Structural Welding Various Base Aluminum Alloys[1,2,3]

Base Metal to Base Metal	1060 1100 3003 Alc. 3003	2014 2219 A201.0	3004 Alc. 3004	5005 5050	5052	5083 5456	5086 514.0 535.0	5154	5454	6005 6061 Alc. 6061 6063 6351 6070	7005 710.0 711.0 712.0	354.0 C355.0	356.0 A356.0 A357.0 359.0 413.0 443.0 A444.0
356.0, A356.0 357.0, 359.0 413.0, 443.0, 444.0	4043 (4)	4145	4043 (4)	4043 (4)	4043 (4)	NR	NR	NR	4043 (4)	5356 (4) (5)	4043 (4)	4145	4043 (10)
354.0, C355.0	4145	4145	4145 (4)	4145 (4)	4145 (4)	NR	NR	NR	NR	4145 (4)	NR	4145 (9)	
7005, 710.0 711.0, 712.0	5356 (5)	NR	5356 (5)	5356 (5)	5356 (5)	5556 (8)	5356 (5)	5356 (5)	5356 (5)	5356 (5)	5556 (5)		
6005, 6061 Alc. 6061, 6063, 6351, 6070	4043 (4)	4145	5356 (4) (5)	5356 (5)	5356 (5)	5356 (5)	5356 (5)	5356 (5)	5356 (5)	5356 (4) (5)			
5454	5356 (5)	NR	5356 (5)	5356 (5)	5356 (5)	5356 (5)	5356 (5)	5554 (5)	5554 (5)				
5154	5356 (5)	NR	5356 (5)	5356 (5)	5356 (5)	5356 (5)	5356 (5)	5554 (5)					
5086, 514.0, 535.0	5356 (5)	NR	5356 (5)	5356 (5)	5356 (5)	5356 (5)	5356 (5)						
5083, 5456	5356 (5)	NR	5356 (5)	5356 (5)	5356 (5)	5556 (8)							
5052	5356 (5)	NR	5356 (5)	5356 (5)	5356 (5)								
5005, 5050	4043 (4) (5)	NR	5356 (4) (5)	5356 (4) (5)									
3004, Alc. 3004	4043 (4) (5)	NR	5356 (5)										
2014, 2219, A201.0	4145	2319 (7)											
1100, 1060, 3003, Alc. 3003	4043 (4) (6)												

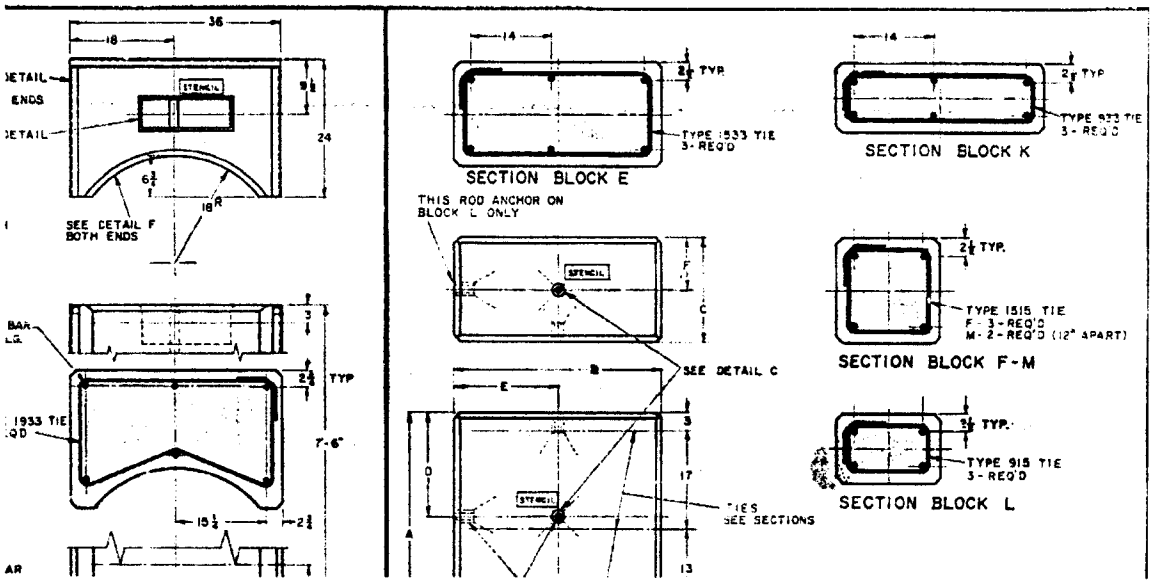
NOTES:
1. This table is designed for structural applications subjected to normal atmospheric conditions. It *does not* apply necessarily to immersed service in fresh or salt water, exposure to specific chemicals, sustained elevated temperatures (above 150 F) or postweld heat treatments.
2. Recommendations in this table apply when using the gas shielded arc welding processes (GTAW and GMAW). NR = Not Recommended.
3. Filler wire shall conform to the requirement on ANSI/AWS A5.10 or A5.10M or ASME SFA 5.10.
4. 4043 or 4047 may be used.
5. 5183, 5356 or 5556 may be used.
6. 1100 may be used.
7. 4145 may be used.
8. 5183 or 5556 may be used.
9. 4009 or C355.0 may be used.
10. 4010 or A356.0 may be used.

I-A 65

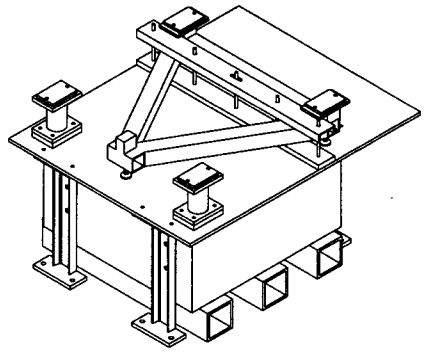
Recommended Aluminum alloy Filler Metals

Filler Alloy‡	1100	4043	5183	5356 5554	5556	5654
Parent Alloy						
1100	3.2	4.8†	—	—	—	—
3003	3.2	5	—	—	—	—
Alclad 3004		5	8	7	8†	—
5052	—	5	8	7	8.5	5
5083	—	—	8	7	8.5	—
5086	—	—	8	7	8.5	—
5154	—	—	8	7	8.5	5
5454	—	5	8	7	8.5	—
5456	—	—	8	7	8.5	—
6005, 6061, 6351	—	5	8	7	8.5	—
6063	—	5*	6.5†	6.5†	6.5†	—

Allowable Shear Stresses in Fillet Welds for Building Type Structure – ksi


SECTION BLOCK E
SECTION BLOCK K
SECTION BLOCK F-M
SECTION BLOCK L
THIS ROD ANCHOR ON BLOCK L ONLY
SEE DETAIL C
SEE SECTIONS
SEE DETAIL F BOTH ENDS
TYP

REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE



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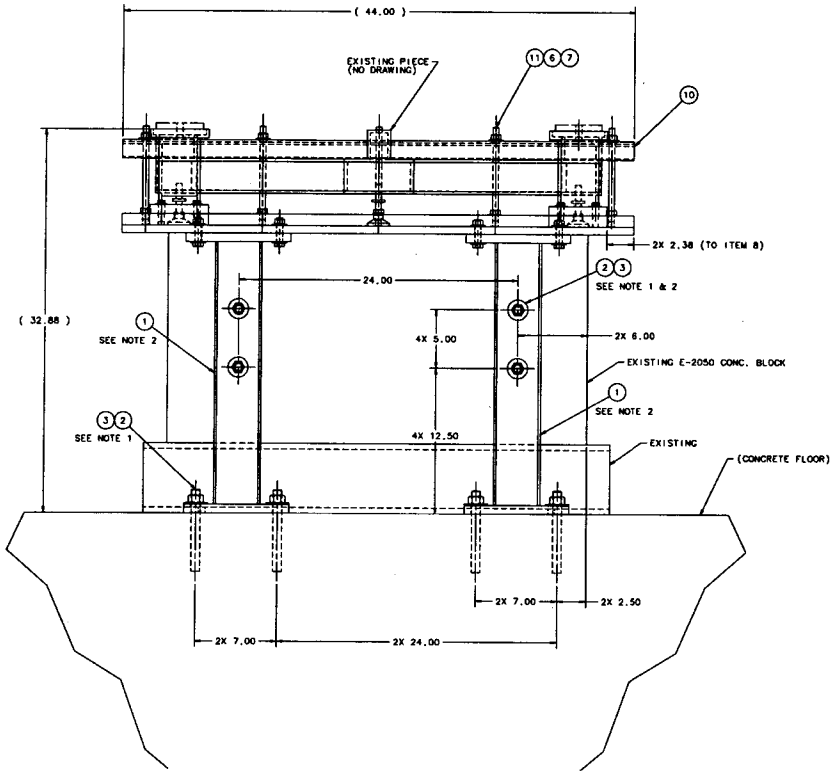
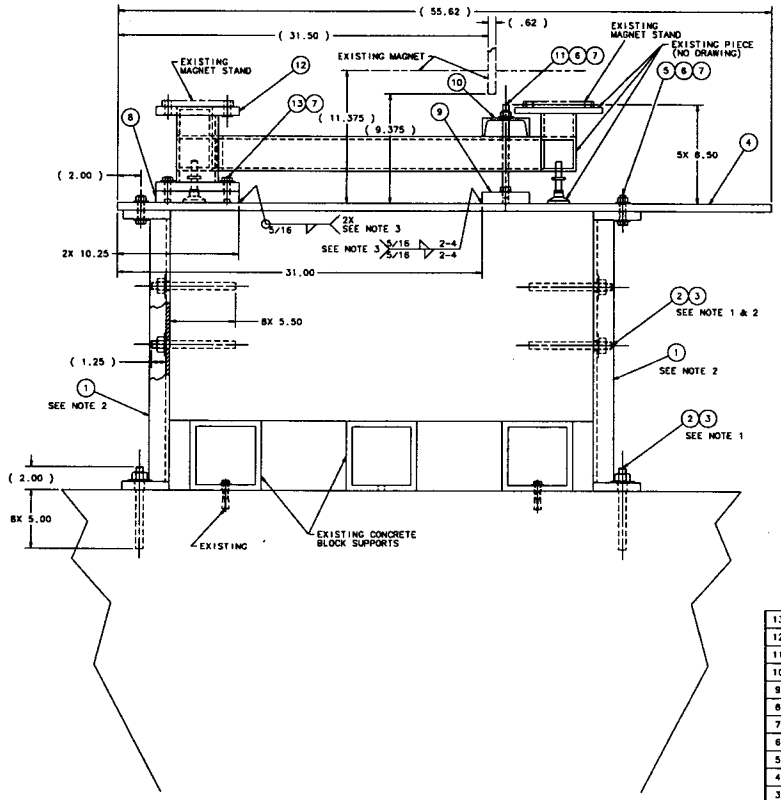




ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
13	1226-063500	HEX HD SCREW, 1/2-13 X 1.5 18-8 S.ST., FERMILAB STOCK	8
12	MC-435261	VERTICAL SUPPORT COLUMN	2
11	93250A033	THREADED ROD, 1/2-13 X 8.0" LG 316 S.ST., MCMASTER CARR	5
10	MD-435260	HORIZONTAL C SUPPORT	1
9	MD-435259	BOSS SUPPORT PLATE, 4 X 44	1
8	MB-435258	BOSS SUPPORT PLATE, 5 X 7	2
7	1218-070000	WASHER, FLAT, 1/2", 18-8 S.ST. FERMILAB STOCK	29
6	1210-074000	NUT, HEX, 1/2-13, 18-8 S.ST. FERMILAB STOCK	18
5	1226-064000	HEX HD SCREW, 1/2-13 X 2.0 18-8 S.ST., FERMILAB STOCK	8
4	MD-435256	BASE PLATE	1
3	1218-074000	WASHER, FLAT, 3/4", 18-8 S.ST. FERMILAB STOCK	16
2	00282519	KB3 3/4 X 7 EXPANSION ANCHOR HILTI CORP.	16
1	MD-435278	LONG VERT. COLUMN, C4	4

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	C.M.LEI	14-APR-2005
.XX	.XXX	ANGLES	DRAWN	R.L.SMITH	21-APR-2005
± .63	± XXX	± X	CHECKED	C.GRIMM	24-MAY-2005
			APPROVED	C.M.LEI	24-MAY-2005
			USED ON	***	
			MATERIAL	SEE PARTS LIST ABOVE	

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

MECHANICAL/EQUIPMENT SUPPORTS STATIONARY SUPPORT MUCOOLER SUPP REINFORCEMENT ASSY

SCALE	DRAWING NUMBER	SHEET	REV
1:4 & NOTED	9209.050-ME-435253	1 OF 1	

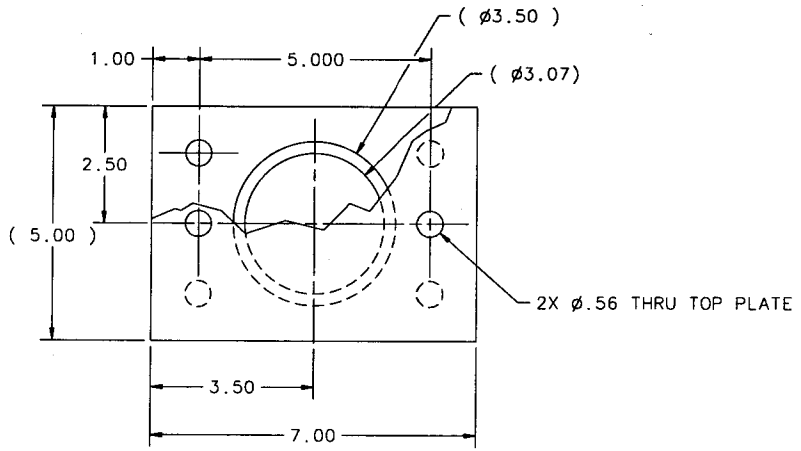
CREATED WITH: Ideas11NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

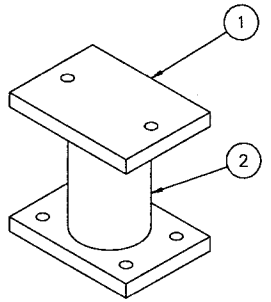
3. USE WELD FILLER ROD ER5356 OR EQUAL.

2. INSTALLATION OF ITEM 1 TO BE PLACED NEXT, OVER HILTI FLOOR ANCHORS.

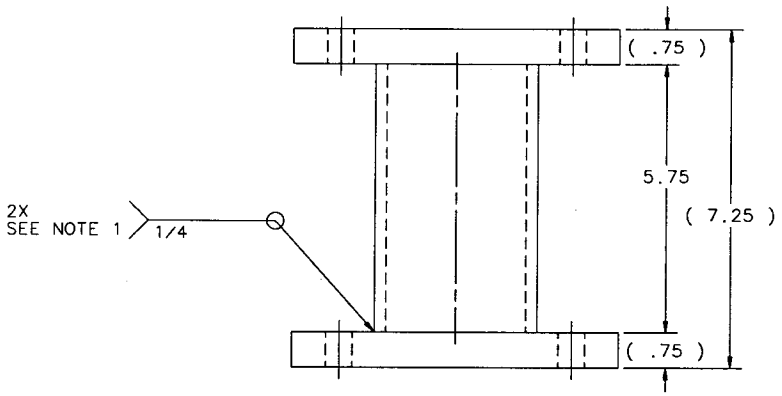
NOTE 1. INSTALL HILTI ANCHOR (ITEM #2) IN FLOOR FIRST.

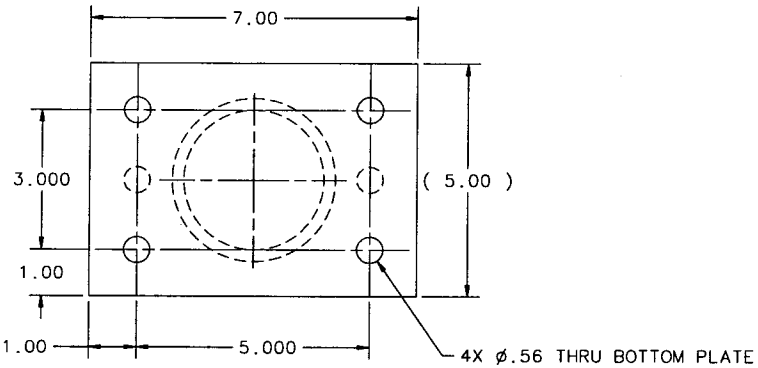
REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE





ISOMETRIC VIEW
NO SCALE





NOTE 1. USE WELD FILLER ROD E308

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
2	COM'L	EXT. PIPE.-3.0" SCH.40, 304 S.ST. ASTM A312 (SUPPLIED BY D.ERICKSON)	1
1	8992K159	BASE-TOP PLATE, .75 THK. X 5.00" 304 S.ST. ASTM A276 MCMASTER CARR	2

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	C.M.LEI	14-APR-2005
.XX	.XXX	ANGLES	DRAWN	R.L.SMITH	21-APR-2005
± .03	± .005	± X	CHECKED	C.GRIMM	24-MAY-2005
			APPROVED	C.M.LEI	24-MAY-2005

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 125
5. DRAWING UNITS: INCHES

USED ON: ME-435253

MATERIAL: SEE PARTS LIST ABOVE

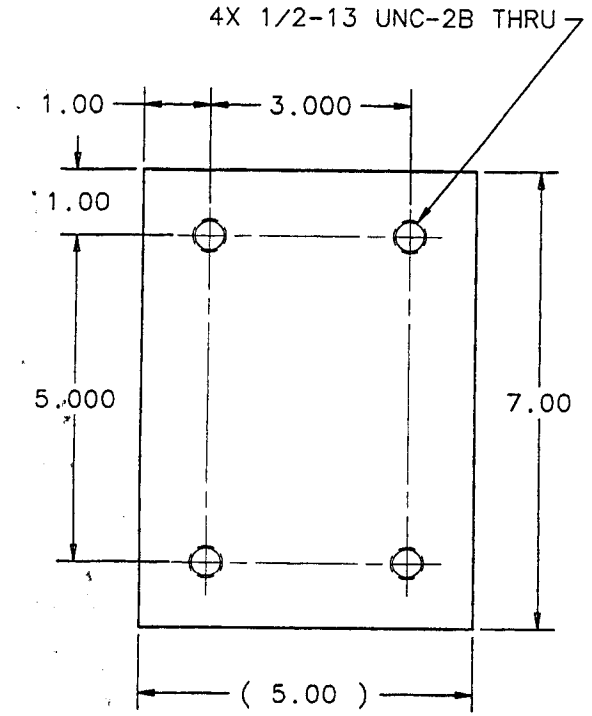
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

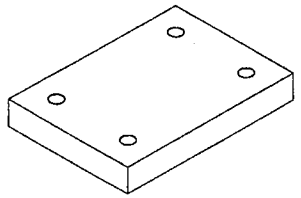
MECHANICAL/EQUIPMENT SUPPORTS STATIONARY SUPPORT MUCOOLER SUPP. -VERT SUPP COLUMN

SCALE	DRAWING NUMBER	SHEET	REV
1:2 & NOTED	9209.050-MC-435261	1 OF 1	

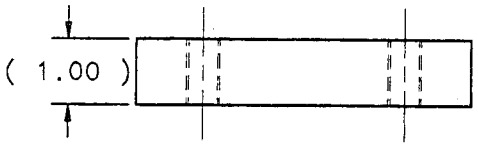
CREATED WITH : Ideas11NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE





ISOMETRIC VIEW
NO SCALE



ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
	PARTS LIST		

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	C.M.LEI	14-APR-200
.XX	.XXX	ANGLES	DRAWN	R.L.SMITH	21-APR-200
± .03	± .005	± X	CHECKED		19/5/0
			APPROVED		19/5/0

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 125
5. DRAWING UNITS: INCCHES

USED ON: ME-435253

MATERIAL: RECT. PLATE, 1.0" THICK X 5.0" WIDE ALUMINUM, 6061-T6, ASTM B221

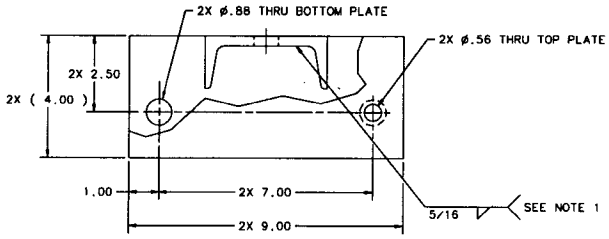
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

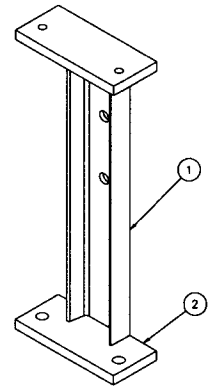
MECHANICAL/EQUIPMENT SUPPORTS STATIONARY SUPPORT MUCOOLER SUPP. -BOSS PLATE 5X7

SCALE	DRAWING NUMBER	SHEET	REV
1:2 & NOTED	9209.050-MB-435258	1 OF 1	

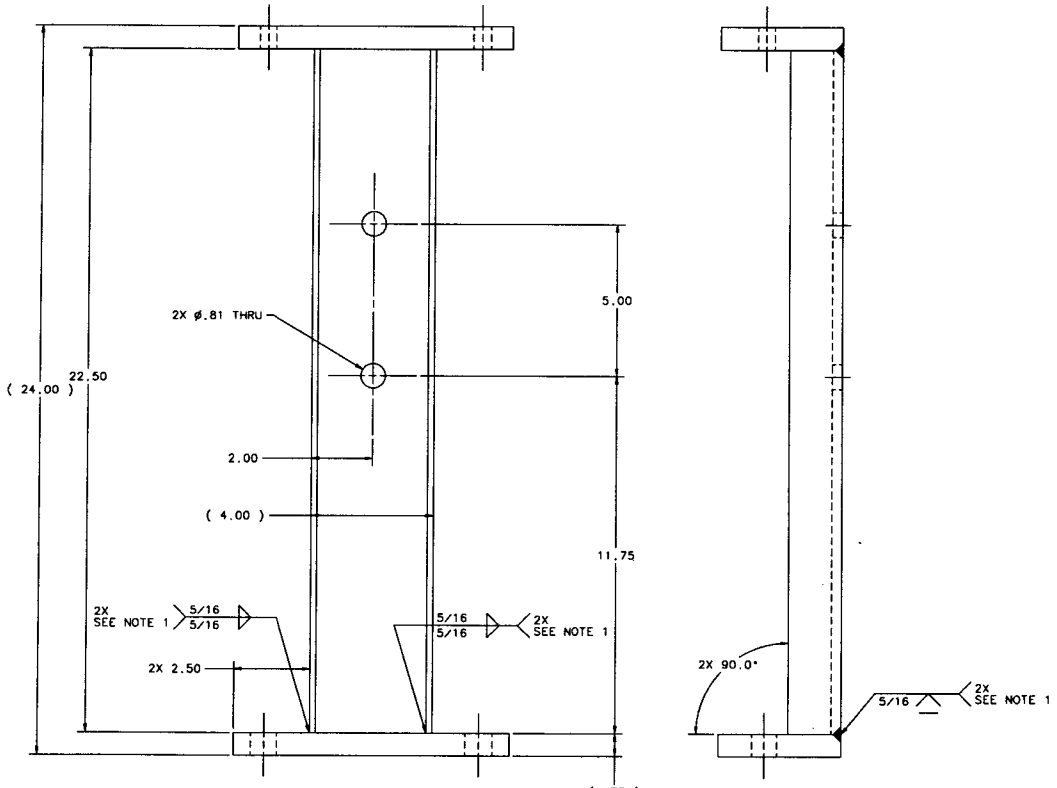
CREATED WITH : Ideas11NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN / APPROVED	DATE





ISOMETRIC VIEW
NO SCALE



NOTE 1. USE WELD FILLER ROD E5356 OR EQUAL

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
2	8975K233	RECTANGLE- 3/4" THK X 4.0", 6061-T6 ALUM. ASTM B221, MCMASTER CARR	2
1	COM'L	C CHANNEL- 4.0"X.320", 6061-T6 ALUMINUM, ASTM B308, (2.50#)	1

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	C.M.LEI	03-MAY-2005
.XX	.XXX	ANGLES	DRAWN	R.L.SMITH	03-MAY-2005
± .03	± XXX	± 1°	CHECKED	C.GRIMM	24-MAY-2005
			APPROVED	C.M.LEI	24-MAY-2005

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAT. ALL MACH. SURFACES 125
5. DRAWING UNITS: INCHES

USED ON: ME-435253

MATERIAL: SEE PARTS LIST ABOVE

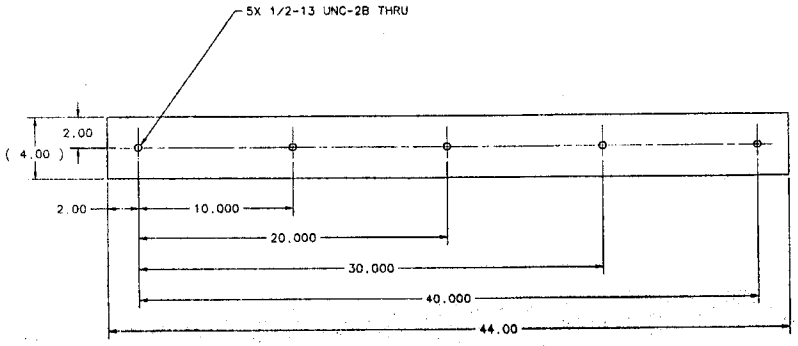
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

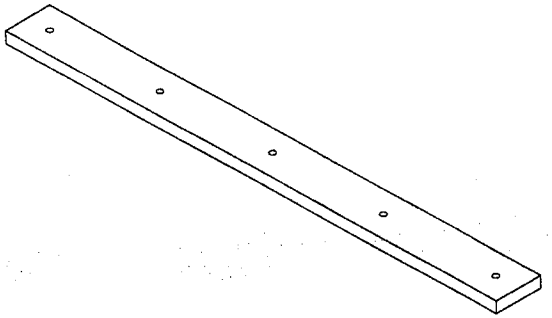
MECHANICAL/EQUIPMENT SUPPORTS
STATIONARY SUPPORT
MUCOOLER SUPP -LNG VER COLUMN C4

SCALE	DRAWING NUMBER	SHEET	REV
1:2 & NOTED	9209.050-MD-435278	1 OF 1	

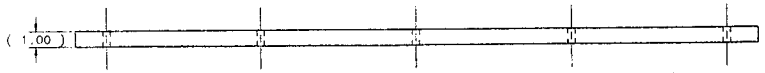
CREATED WITH : Ideas11NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

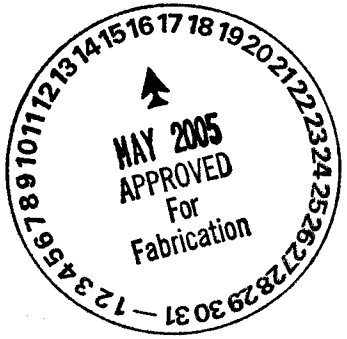
REV	DESCRIPTION	APPROVED	DATE





ISOMETRIC VIEW
NO SCALE





ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	C.M.LEI	14-APR-2005
XX	.XXX	ANGLES	DRAWN	R.L.SMITH	22-APR-2005
± .03	± .005	± X	CHECKED		18-MAY-05
			APPROVED		18/MAY/05

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 125
5. DRAWING UNITS: INCHES

USED ON: ME-435253

MATERIAL: RECT. PLATE, 1.0" THK X 4.0" (4.70# /FT.) ALUMINUM, 6061-T6, ASTM B221

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

MECHANICAL/EQUIPMENT SUPPORTS
STATIONARY SUPPORT
MUCOOLER SUPP. -BOSS PLATE 4X44

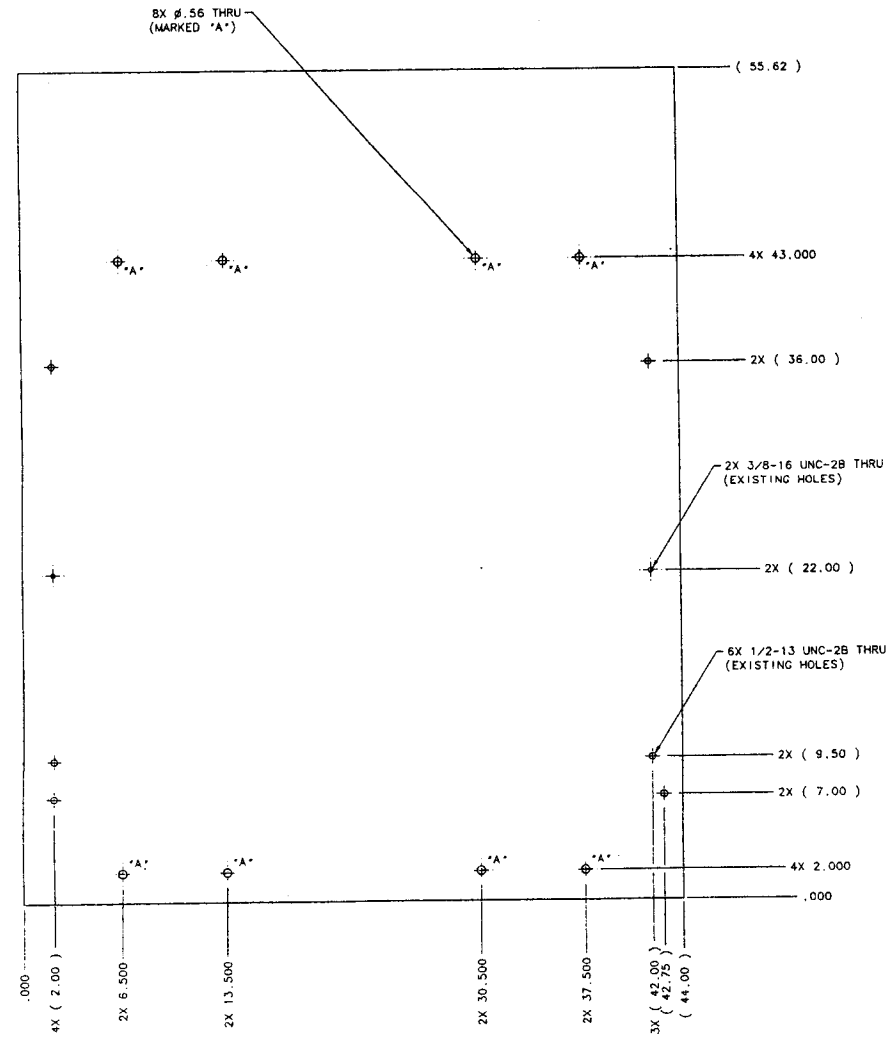
SCALE	DRAWING NUMBER	SHEET	REV
1:2 & NOTED	9209.050-MD-435259	1 OF 1	

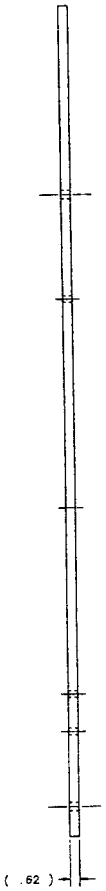
CREATED WITH : Ideas11NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

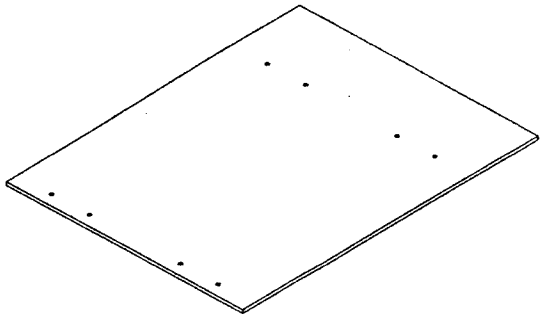
8 7 6 5 4 3 2 1

D C B A

REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE







ISOMETRIC VIEW
NO SCALE
(NEW HOLES SHOWN ONLY)

MAY 2005
APPROVED
For
Fabrication

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	C.M.LEI	14-APR-2005
.XX	.XXX	ANGLES	DRAWN	R.L.SMITH	21-APR-2005
± .03	± .005	± X	CHECKED		18-MAY-05
			APPROVED		17-5-05

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994.
4. MAX. ALL MACH. SURFACES 125

5. DRAWING UNITS: INCHES

USED ON: ME-435253

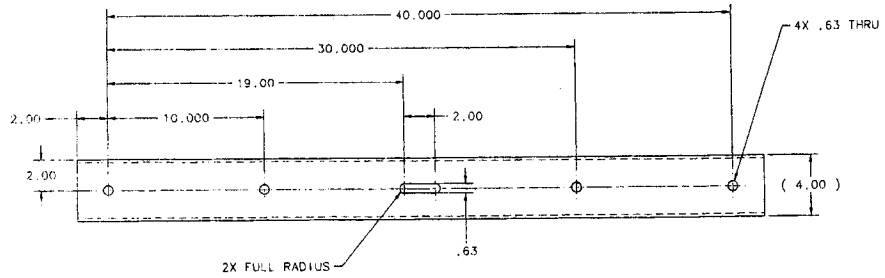
MATERIAL: EXISTING 5/8 THICK ALUMINUM PLATE

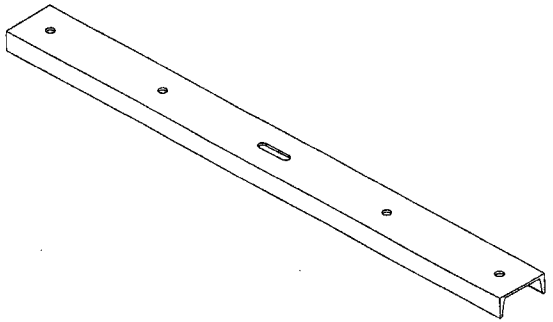
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

MECHANICAL/EQUIPMENT SUPPORTS STATIONARY SUPPORT MUCOOLER SUPPORT -BASE PLATE

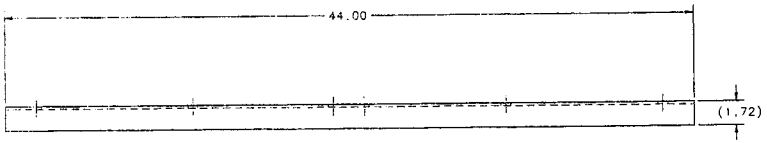
SCALE	DRAWING NUMBER	SHEET	REV
1:1 & NOTED	9209.050-MD-435256	1 OF 1	

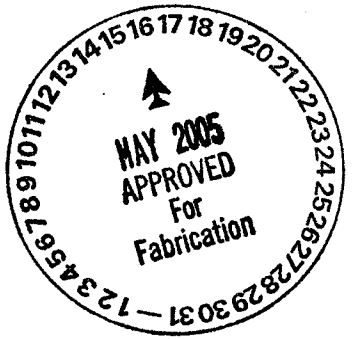
CREATED WITH : IdeasINXSeries | GROUP: PPD/MECHANICAL DEPARTMENT





ISOMETRIC VIEW





ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	C.M.LEI	14-APR-2005
.XX	.XXX	ANGLES	DRAWN	R.L.SMITH	21-APR-2005
± .03	± .005	± 1°	CHECKED		18 MAY 05
			APPROVED		

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 125
5. DRAWING UNITS: INCHES

USED ON: ME-435253

MATERIAL: C CHANNEL, 4.0" X .18" (1.85# /FT.) ALUMINUM, 6061-T6, ASTM B308

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

MECHANICAL/EQUIPMENT SUPPORTS
STATIONARY SUPPORT
MUCOOLER SUPP. -HORZ C SUPPORT

SCALE	DRAWING NUMBER	SHEET	REV
1:4	9209.050-MD-435260	1 OF 1	

CREATED WITH : IdeasTINXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

Fermi National Accelerator Laboratory
PPD / Mechanical Support / Engineering Analysis

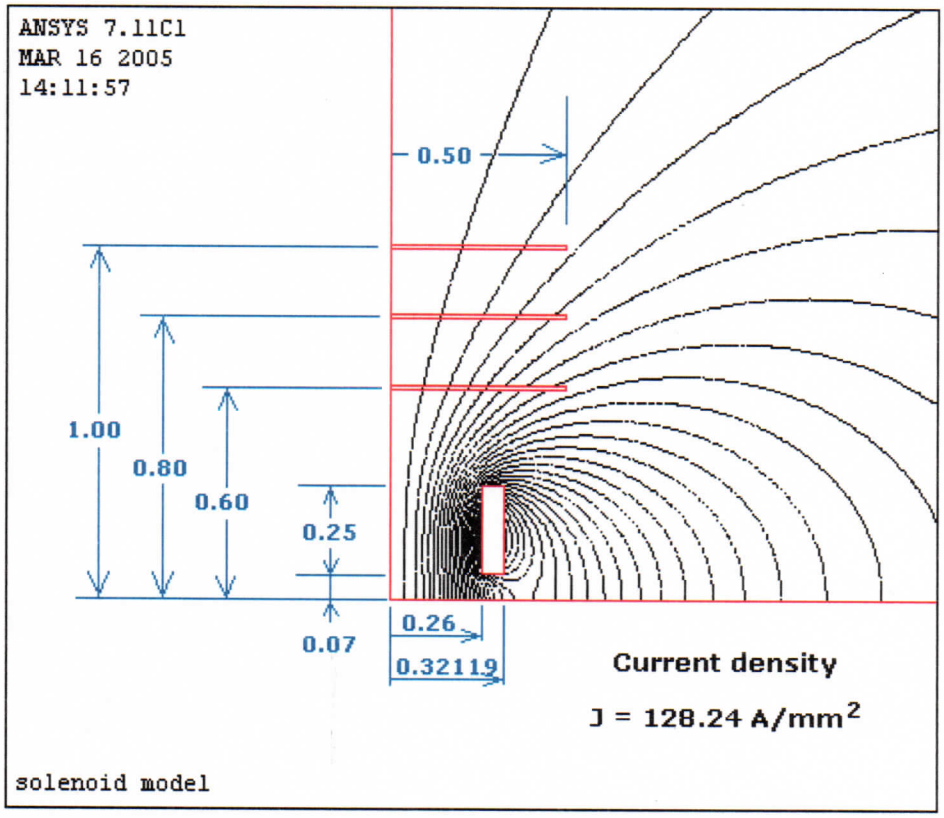
Magnetic Force on a Steel Plate near Solenoid

Zhijing Tang
March 17, 2005

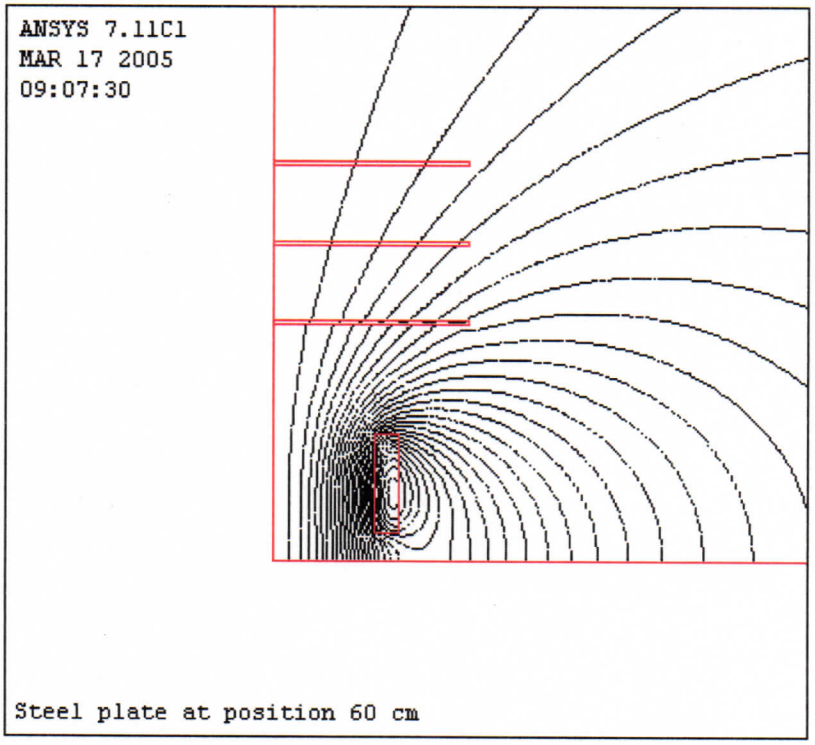
There have been some concerns that steel objects may come near the solenoid during operation. These steel objects may experience large magnetic force, and hence causing damage to person near by or the solenoid itself. This analysis is to give some estimates that how large the magnetic force will be.

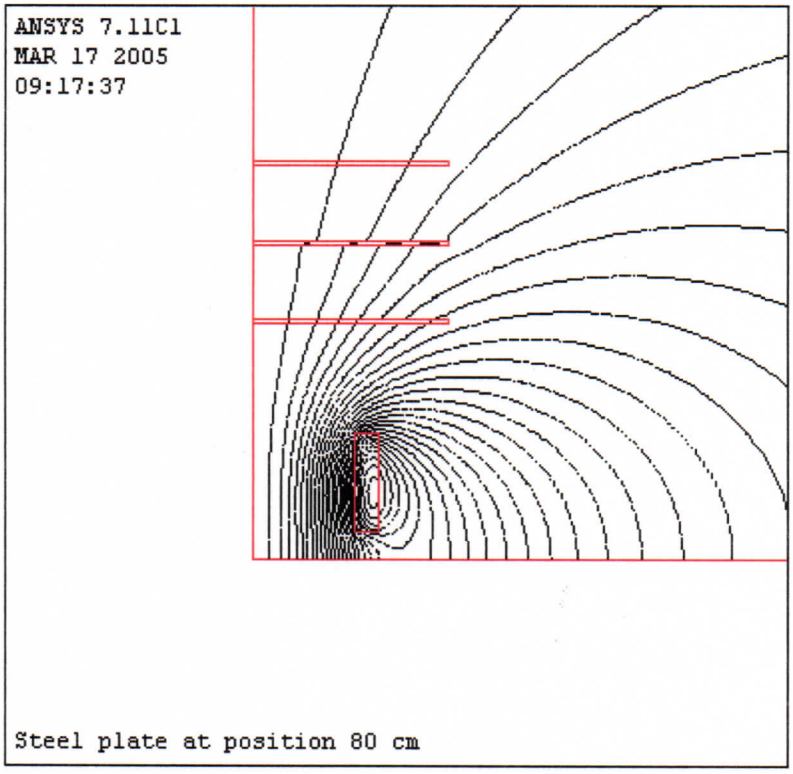
To simplify the analysis, we consider an axi-symmetric problem: A steel plate of 1 cm thick and 1 m diameter is placed along the axis of the solenoid, as shown in Fig.1. Also shown in the figure is the geometry of the coil (unit is meter). The current in the coil is (0.32119-0.26)(0.25)(128.24) = 1.96×10^6 A. There are two coils, so the total current is 3.92×10^6 A.

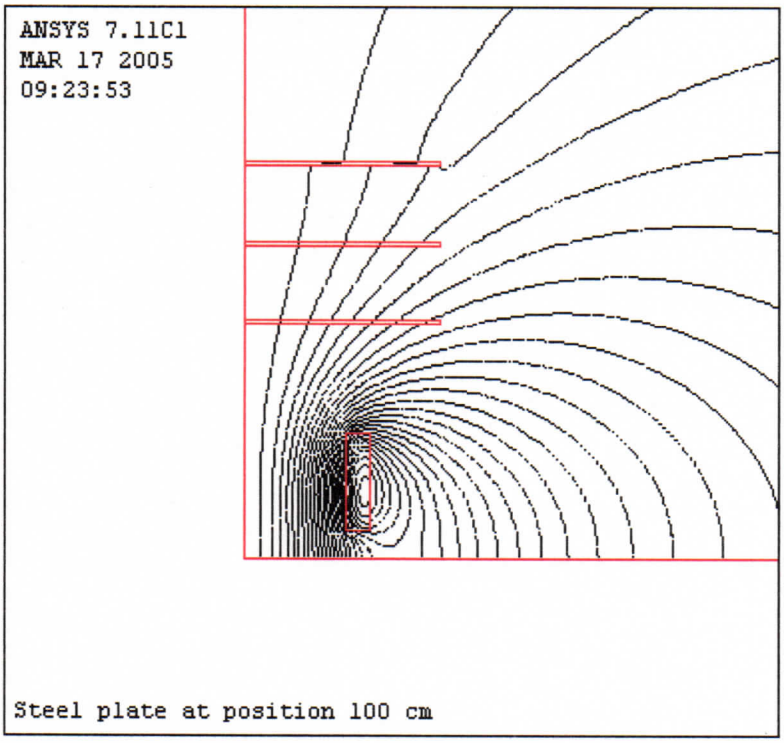
The magnetic field at the center of solenoid is about 5 T. The magnetic force on the steel plate is calculated for three positions using both virtual work method and Maxwell stress tensor. The results are listed in Table I.



Steel Plate Position	Calculation Method	Magnetic Force (N)	Magnetic Force (lb)
60 cm	Virtual Work	28068	6310
	Maxwell Stress	21701	4879
80 cm	Virtual Work	9282	2087
	Maxwell Stress	7921	1781
100 cm	Virtual Work	3398	764
	Maxwell Stress	2960	665




ANSYS 7.1IC1
MAR 17 2005
09:17:37
Steel plate at position 80 cm

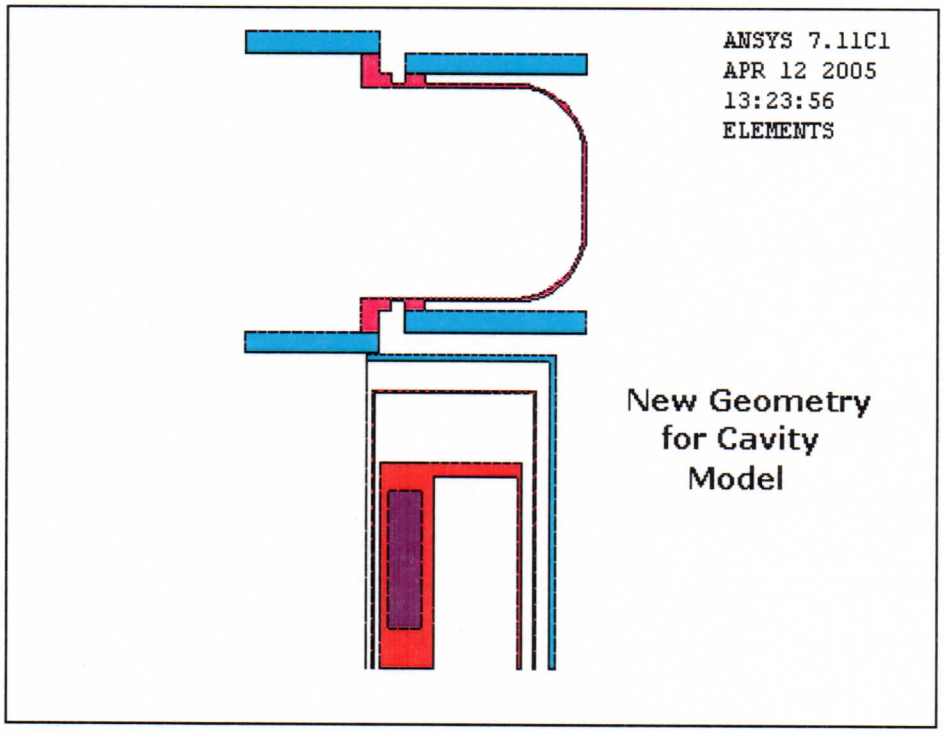

ANSYS 7.1IC1
MAR 17 2005
09:23:53
Steel plate at position 100 cm

Fermi National Accelerator Laboratory
PPD / Mechanical Support / Engineering Analysis

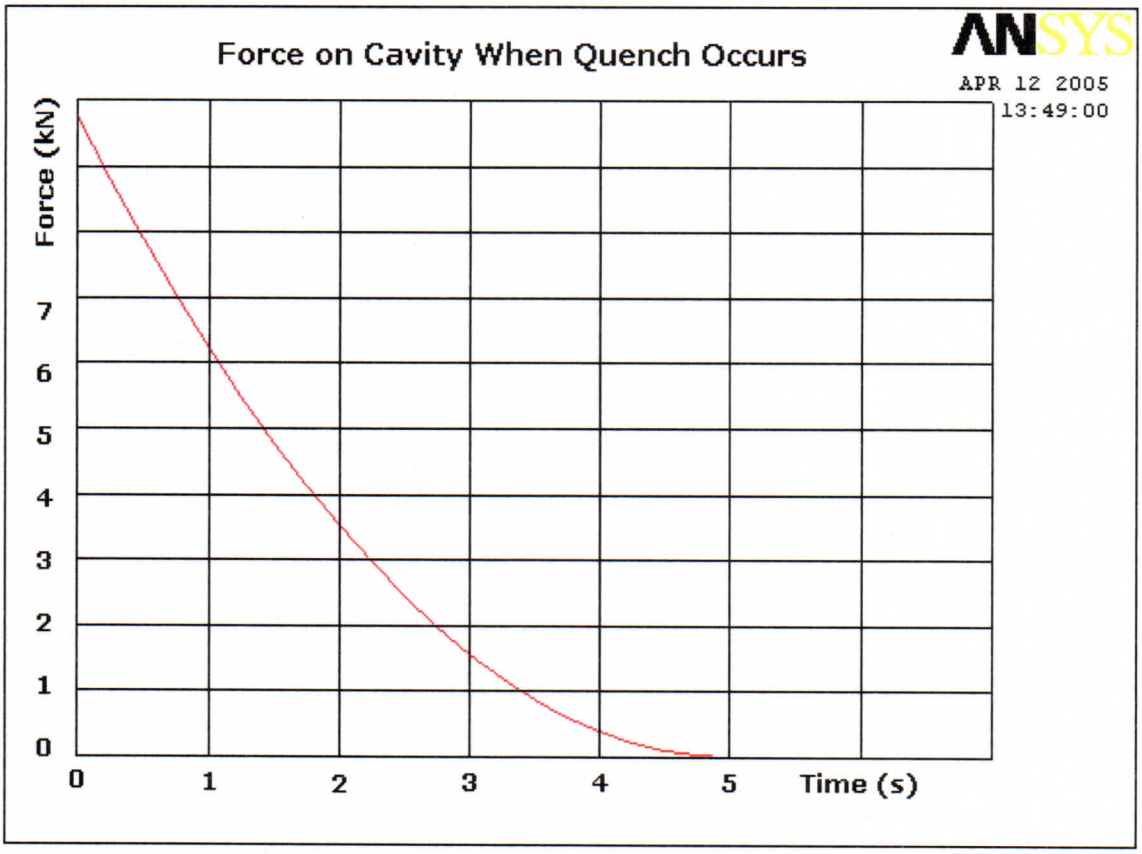
Magnetic Force on a Cavity near Solenoid (New Cavity Geometry)

Zhijing Tang
April 13, 2005

This analysis calculates the magnetic force on a cavity near the solenoid when quench occurs. This new cavity geometry has more material than previous model. The thickness of the copper is 6.096 mm instead of 6 mm. The thickness of the stainless steel is 38.1 mm instead of 37.5 mm. And there is another stainless steel plate added. As shown in Fig.1. The solenoid is the same as in the previous model.



The maximum force on the cavity during quench is 9741 N, or 2190 lb. The result is in Fig.2.


Force on Cavity When Quench Occurs
ANSYS
APR 12 2005
13:49:00
Force (kN)
0
1
2
3
4
5
6
7
0
1
2
3
4
5
Time (s)